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UPGRADING HOPPERS FOR BATCHING BULK MATERIALS

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Some designs of Hopper batchers for a two-speed batching regime for bulk materials using feeders with an unregulated one-speed drive are examined.

Key words: batching accuracy, bulk material, hopper, loading rate unit, fine-feed cell, internal funnel, unregulated one-speed drive.

The random and dynamic errors in weighing and batching bulk materials in the production of glass batch depend not only on the measurement accuracy for the batched portions of raw material and the effectiveness of the algorithms used for digital control of the loading and unloading of strain-gauge batchers but also on the structural characteristics of hopper batching setups equipped with vibratory screw and gravity feeders.

As a rule, feeders operating in a two-speed regime with ‘rough’ and ‘fine’ feeding of material are used to attain a prescribed accuracy in weighing out the components of the batch, which is accomplished either by regulating the rotation speed and intensity of the oscillations of the working units of the drive mechanisms or by changing the diameter of the screws and pitch of the winding of the screw blades or by increasing or decreasing the cross section of the loading and unloading openings equipped with disks and sector flaps. However, there exist a number of technical solutions [1, 2] where two-speed unloading of bulk and clumping materials from the scales operating according to the principle of unloading with a residual tare is accomplished with the aid of one-speed feeding mechanisms, which reduces their capacity without any additional controlling action.

This approach from one weigh-out regime to another in most similar designs is realized by the formation of a residual portion of the material in the ‘fine’ feed cell formed by a separating barrier located at the bottom of the conical part of the batcher. But, since the weight (mass) of this portion is a variable quantity and depends on the varying physical-mechanical characteristics of the raw material and other destabilizing factors, it is important to avoid accumulation of raw material, which makes it necessary to decrease the positive batching errors, optimize the ‘loading’ rate time and decrease the height of the column of the material falling inside the weighing hopper. In this case it is difficult to accomplish stable reduction of the errors associated directly with the height of the columns of falling material solely by algorithmic methods without making changes in the interior volume of the weighing hopper.

One design of a batcher with such modifications [3], proposed by the present author, functions as follows. A command from the control system opens the feed gate *1* (Fig. 1*a*) and the material from the head hopper *2* starts to flow into the dispenser *3* through the load rate unit *4*, placed concentrically in the top part of the hopper setup and implemented in the form of a flared tube segment *5*.

In the loading process the bulk material gradually fills the interior volume of the weighing hopper and forms in it a conical hill *6* whose apex at definite moment in time, which depends on the size of the weighed of raw material and its angle of repose, reaches the lower level of the rate unit. If the installation dimensions of this unit are picked to that the position of its bottom edge coincides with the predicted height of the pile of material at the completion of loading, then the small remaining portion of the residual raw material does not flow along the surface of the material inside the batcher, but rather the it rises intensely in the vertical tube *5*, thereby decreasing its fall distance (Fig. 1*b*).

After of the ‘loading’ operation is completed the two-speed unloading of the weighing hopper starts, in the course of which the gate *7* opens and the material pours onto a gathering conveyer *11* (Fig. 1*c*) or other continuous transport mechanism through the calibrated openings *8*, *9* located in the unloading diaphragm *10*. Since the diameter of the opening *8* corresponding to the ‘rough’ feed is 2 – 5 times larger than the diameter *9* of the ‘fine’ topping feed, the material from the volume bounded by the side walls of the batcher, the separating barrier *12* and the section of the diaphragm *10*

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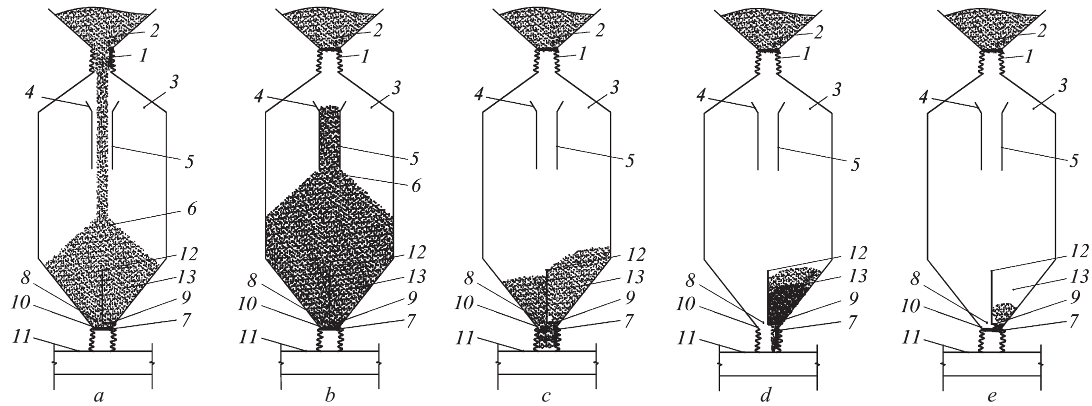

Fig. 1. Weighing hopper with a fine-feed cell and loading rate unit: *a*) initial phase of loading; *b*) filling of the loading rate unit; *c*) initial phase of loading; *d*) transition to the fine-feed regime; *e*) unloading finish.

with the opening *8*, is unloaded more intensely than from the 'fine' topping feed cell *13* with the opening *9*. As a result there comes a moment when the dispensed raw material remains only in this cell, and the material is unloaded from it more slowly (Fig. 1*d*).

It is obvious that such a transition to 'fine' feed unloading without additional controlling action is necessary in order that at the end of the metering cycle the volume of the material corresponding to the residual tare does not exceed the volume of the material in the 'fine' topping feed cell (Fig. 1*e*). Otherwise, the prescribed portion of the component of the glass batch is off-loaded from the batcher up to the moment of the unregulated transition into the 'fine' topping feed regime, which in turn will lead to the appearance of weighing-out errors associated with the lead time for the closure of the unloading gate *7*. In order to minimize these errors, which are due to the accumulation of positive loading errors the metered raw material and the growth of the residual tare, which is conventionally zeroed before each dispensing cycle, an automatic adjustment of the load lead time, which affects the height of the column of falling material, must be made.

In this connection the presence of the load rate unit expands the functional possibilities of controlling the batching, since even a very small change in the prescribed residual tare makes it possible to vary in a wide range the height of the column of falling material bounded by the walls of the concentrically positioned tube *5*. In addition, by varying the diameter and height of this tube it is possible to optimize and stabilize for different bulk components of the batch the optimal moment of closure of the feeding flap *1* at the end of the 'rough' feed of material into the weighing batcher operating in a two-speed unregulated feed drive.

The use of such one-speed feeders for dispensers functioning by the principle of fine two-speed loading and complete (no residual tare) unloading of material from the weighing hopper is limited by the complexity of the formation of a definite volume of material intended for unregulated transition from 'rough' loading to 'fine' feeding of the batched raw material from the weighing feeding hopper. Such limitations are also associated with the fact that in the weighing feeding hopper, whose volume is usually figured for many batching cycles, it is impossible to position the fine topping feed cell for a single weighing operation and to use instead an interior funnel with openings, though this makes it possible to implement two-speed batching, but increases the length of the entire batch-preparation cycle [4]. For this reason, it is best to attach such additional equipment in the feeding hoppers in the low-capacity charging-mixing lines equipment with, for example, electric-drive weighing trucks operating in the manual and semi-automatic operating regimes.

In general an electric-drive weighing truck is a multicomponent moving batcher, which moves successively from one feed hopper to another and is successively loaded with the required materials which are part of the composition of the batch being prepared. During loading the truck operator opens, either manually or with the aid of a pneumatic drive, the appropriate flap and starts to feed the raw material into the weighing bin of the truck in the 'rough' regime. Then, to avoid overloading or uncontrollable collapse of the material after the accumulation of 90 – 95% of the weight of a prescribed portion, the operator proceeds to open or close the flap several times in order to decrease the feed rate of the raw material being batched. All this either decreases the metering accuracy or increases the total cycle for composing the multicomponent mixture.

In contrast to ordinary hoppers, which possess a rectangular or cylindrical shape with an unloading cone at the bottom, a feed hopper equipped with an additional interior funnel makes it possible to avoid these deficiencies, since the transition from 'rough' feeding of the material into 'fine' topping feeding in the improved design is done without the participation of the operator.

Before such a hopper *1* starts to operate (Fig. 2*a*) the batched material *2*, fed through an unloading opening *3*, gradually fills the top cylindrical part *4*. At the same time the material flows through the openings *5* (located along the cone) and the opening *6* (located at the base of the cone) of the interior funnel *7* flows into the additional cell *8*, formed by the bottom conical part *9* of the hopper *1* and the funnel *7*.

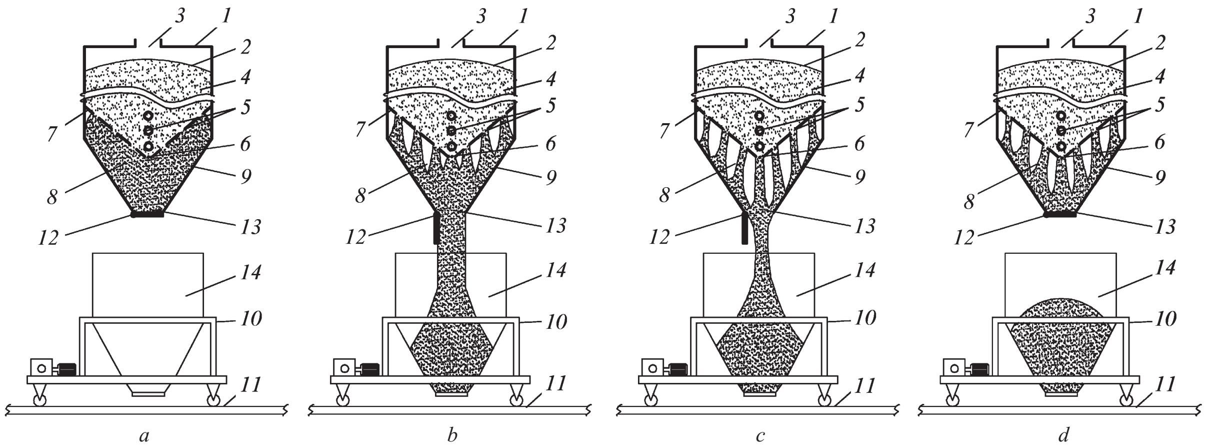

Fig. 2. Weighing feed hopper with an additional internal funnel: *a*) initial state; *b*) unloading of the material in the 'rough' feeding regime; *c*) transition into the 'fine' topping regime; *d*) completion of unloading and preparation for the next batching cycle.

As this cell, whose volume should not exceed that of the batched portion in the 'rough' feed regime, is filled the openings *5* and *6* in the interior funnel *7* are self-closed by the loaded material and its further outflow from the top part of the feeding hopper *1* into the bottom hopper stops.

When all feed hoppers are ready the operator rides on an electric weighing truck *10*, moving on the rails *11*, to the bunker set by the process regulations, and opens the unloading flap *12*, placed on the outflow opening *13*. The bulk batched material starts to flow in the 'rough' feeding regime out of the bottom conical part *9* of the bunker *1* and rapidly fills the weighing bin *14* of the truck *10* (Fig. 2*b*).

After 30 – 60 sec the entire preaccumulated portion of material, corresponding to 90 – 95% of the weight of the batched raw material, is unloaded from the cell *8*, the rapid unloading of the truck stops but the material continues to be fed into it through the openings *5* and *6* and the open flap *12* (Fig. 2*c*).

Since the total area of these openings is 3 – 10 times smaller than that of the output opening *13* of the weighing feed hopper *1*, the intensity of the filling of the weighing cell *14* decreases, which permits unregulated transition to 'fine' topping feeding of the material. For example, the area of the outflow opening *13* with diameter 20 cm is 314 cm^2 and the total area of the *13* openings *5* and *6* (their number depends on the ratio of batching rates) with diameter 3 cm equals 92 cm^2. That is, the topping of the material in the 'fine' feed regime will be performed 3.3 times more slowly.

In this case it is easier for the operator to fix the final weight, controlled with the aid of a dial or a digital measuring terminal, since the manual closure of the unloading gate *12* with a small flow of batched raw material is much more easily implemented than with a large flow. In addition, the accuracy of the batched feeding of raw material into the weighing truck is increased and there is no disruption and collapse of the material from the weighing feed hopper.

At the completion of the 'fine' topping feed operation the operator puts the unloading gate *12* into the initial closed state and the bulk material in the hopper from which the batching is performed starts to fill through the openings *5* and *6* the cell *8*, preparing it for a new batching cycle (Fig. 2*d*). It should be noted that the filling time of the cell *8*, which depends on the number and diameter of the openings *5* and *6*, can be 2 – 3 min. But since the total time for the successive accumulation of all portions of the components weighed out with aid of the electric weighing truck ranges from 5 to 10 min, by the next cycle the first weighing feed hopper will be ready for next two-speed feeding of material into the weighing truck or a different weighing feeder.

However, if the time of the preparation cycle for the glass batch exceeds 10 min, then the number of additional openings in the funnel *8* can be reduced, which will result in some reduction of the capacity of the 'loading' operation in the 'fine' regime but the metering of the material will be more accurate.

In summary, equipping the hopper feed setups and weighing feed hopper with 'fine' unloading cells with loading rate units and 'rough' feed cells greatly improves the accuracy of two-speed batching of the bulk components of the batch when using unregulated one-speed feeders and unloaders.

REFERENCES

1. V. V. Efremenkov, V. N. Berezin, V. S. Rozhkov, et al., "Improving the proportioning of raw components of a glass mixture," *Steklo Keram.*, No. 3, 7 – 9 (1996); V. V. Efremenkov, V. N. Berezin, V. S. Rozhkov, et al., "Improving the proportioning of raw components of a glass mixture," *Glass and Ceram.*, **53**(3 – 4), 66 – 68 (1996).
2. V. V. Efremenkov, V. P. Chalov, V. V. Tarbaev, et al., "Two-screw feeders for proportioning hygroscopic clumping components of glass batch," *Steklo Keram.*, No. 8, 17 – 18 (1998).
3. V. V. Efremenkov and V. P. Chalov, "Setup for proportioning bulk components of glass batch, RF Patent 2117641, IPC C03B 3/00," published August, 20, 1998; *Byul. Izobr.*, No. 23 (1998).
4. V. V. Efremenkov, "Hopper proportioning setup for bulk materials, RF Patent 137367, IPC G01F11/00," published February 10, 2014; *Byul. Izobr.*, No. 1 (2014).